growths is also insignificant, and out of proportion to the carbonic acid evolved. We must therefore in this case decline to accept the root-absorption hypothesis, and admit that the carbonic acid has arisen as a result of the cell-growth in the plant.

Passing to the chlorophyl-bearing plants, we find that in the Phanerogamia it is only the green parts that at any time exhale oxygen, and then only under the influence of sunshine. The other parts of the plant above the ground that are not green, viz. the stem, twigs, flowers, &c., are at all times, day and night, exhaling carbonic acid. The whole history of the plant, from the time the seed is planted till its death, is a continuous story of oxidation, *except when sunlight is falling on the leaves.* The seed is put into the ground; and during germination oxygen is absorbed and carbonic acid exhaled. If the seedling is kept in the dark, oxygen is never exhaled, only carbonic acid, and the plant not only grows, but all visible structures, except flowers, are formed in a rudimentary condition. In the light, the growth during the night time is attended by the evolution of carbonic acid, while during the daytime the bark of the stem and branches is throwing off carbonic acid. When flowers and seeds form, the evolution of carbonic acid attending this highest act of which the plant is capable is often greater than that produced at any time in many animals.

Every thing in the history of plants therefore tends to show that the evolution of their structures is inseparably attended by the formation of carbonic acid; and it seems impossible, when we consider the evolution alone, to arrive at any other opinion than that already expressed—that *all living things, whether plant or animal, absorb oxygen and evolve carbonic acid, or some other oxidized substance, as an essential condition of the evolution of their structures.*

College of the City of New York,
Sept. 12th, 1872.

VII.—Sequoia *and its History.* By Professor Asa Gray, President of the American Association for the Advancement of Science*.

The session being now happily inaugurated, your presiding officer of the last year has only one duty to perform before he surrenders his chair to his successor. If allowed to borrow a simile from the language of my own profession, I might liken

* An address delivered at the meeting held at Dubuque, Iowa, August 1872.

the President of this association to a biennial plant. He flourishes for the year in which he comes into existence, and performs his appropriate functions as presiding officer; when the second year comes round, he is expected to blossom out in an address and disappear. Each president, as he retires, is naturally expected to contribute something from his own investigations or his own line of study, usually to discuss some particular scientific topic.

Now, although I have cultivated the field of North-American botany with some assiduity for more than forty years, have reviewed our vegetable hosts, and assigned to no small number of them their names and their place in the ranks, yet, so far as our own wide country is concerned, I have been to a great extent a closet botanist. Until this summer I had not seen the Mississippi, nor set foot upon a prairie.

To gratify a natural interest, and to gain some title for addressing a body of practical naturalists and explorers, I have made a pilgrimage across the continent. I have sought and viewed in their native haunts many a plant and flower which for me had long bloomed unseen, or only in the *hortus siccus*. I have been able to see for myself what species and what forms constitute the main features of the vegetation of each successive region, and record (as the vegetation unerringly does) the permanent characteristics of its climate.

Passing on from the eastern district, marked by its equably distributed rainfall, and therefore naturally forest-clad, I have seen the trees diminish in number, give place to wide prairies, restrict their growth to the borders of streams, and then disappear from the boundless drier plains, have seen grassy plains change into a brown and sere desert—desert in the common sense, but hardly anywhere botanically so,—have seen a fair growth of coniferous trees adorning the more favoured slopes of a mountain-range high enough to compel summer showers—have traversed that broad and bare elevated region shut off on both sides by high mountains from the moisture supplied by either ocean, and longitudinally intersected by sierras which seemingly remain as naked as they were born—and have reached at length the westward slopes of the high mountain-barrier which, refreshed by the Pacific, bears the noble forests of the Sierra Nevada and the coast-range, and among them trees which are the wonder of the world. As I stood in their shade in the groves of Mariposa and Calaveras, and again under the canopy of the commoner redwood, raised on columns of such majestic height and ample girth, it occurred to me that I could not do better than to share with you, upon this occasion, some of the thoughts which possessed my mind.

In their development they may, perhaps, lead us up to questions of considerable scientific interest.

I shall not detain you with any remarks (which would now be trite) upon the size or longevity of these far-famed Sequoia trees, or of the sugar-pines, incense-cedar, and firs associated with them, of which even the prodigious bulk of the dominating Sequoia does not sensibly diminish the grandeur. Although no account and no photographic representation of either species of the far-famed Sequoia trees give any adequate impression of their singular majesty, still less of their beauty, yet my interest in them did not culminate merely or mainly in considerations of their size and age. Other trees in other parts of the world may claim to be older; certain Australian gum-trees (*Eucalypti*) are said to be taller. Some, we are told, rise so high that they might even cast a flicker of shadow upon the summit of the pyramid of Cheops; yet the oldest of them doubtless grew from seed which was shed long after the names of the pyramid-builders had been forgotten. So far as we can judge from the actual counting of the layers of several trees, no Sequoia now alive can sensibly antedate the Christian era.

Nor was I much impressed with an attraction of man's adding. That the more remarkable of these trees should bear distinguishing appellations seems proper enough; but the tablets of personal names which are affixed to many of them in the most visited groves (as if the memory of more or less notable people of our day might be made more enduring by the juxtaposition) do suggest some incongruity. When we consider that a hand's breadth at the circumference of any one of the venerable trunks so placarded has recorded in annual lines the lifetime of the individual thus associated with it, one may question whether the next hand's breadth may not measure the fame of some of the names thus ticketed for adventitious immortality. Whether it be the man or the tree that is honoured in the connexion, probably either would live as long, in fact and in memory, without it.

One notable thing about these Sequoia trees is their *isolation*. Most of the trees associated with them are of peculiar species; and some of them are nearly as local. Yet every pine, fir, and cypress in California is in some sort familiar, because it has near relatives in other parts of the world; but the redwoods have none. The redwood (including in that name the two species of "big trees") belongs to the general cypress family, but is *sui generis*. Thus isolated systematically, and extremely isolated geographically, and so wonderful in size and port, they, more than other trees, suggest questions.

Were they created thus local and lonely, denizens of Cali-

fornia only—one in limited numbers in a few choice spots on the Sierra Nevada, the other along the coast-range from the Bay of Monterey to the frontiers of Oregon? Are they veritable Melchizedecs, without pedigree or early relationship, and possibly fated to be without descent?

Or are they now coming upon the stage (or rather were they coming but for man's interference) to play a part in the future?

Or are they remnants, sole and scanty survivors of a race that has played a grander part in the past, but is now verging to extinction? Have they had a career? and can that career be ascertained or surmised, so that we may at least guess whence they came, and how and when?

Time was, and not long ago, when such questions as these were regarded as useless and vain, when students of natural history, unmindful of what the name denotes, were content with a knowledge of things as they now are, but gave little heed as to how they came to be so. Now such questions are held to be legitimate, and perhaps not wholly unanswerable. It cannot now be said that these trees inhabit their present restricted areas simply because they are there placed in the climate and soil of all the world most congenial to them. These must indeed be congenial or they would not survive. But when we see how Australian *Eucalyptus* trees thrive upon the Californian coast, and how these very redwoods flourish upon another continent—how the so-called wild oat (*Avena sterilis*) of the Old World has taken full possession of California —how that cattle and horses, introduced by the Spaniard, have spread as widely and made themselves as much at home on the plains of La Plata as on those of Tartary, and that the cardoon-thistle seeds, and others they brought with them, have multiplied there into numbers probably much exceeding those extant in their native lands; indeed, when we contemplate our own race and our own particular stock taking such recent but dominating possession of this New World—when we consider how the indigenous flora of islands generally succumbs to the foreigners which come in the train of man, and that most weeds (*i. e.* the prepotent plants in open soil) of all temperate climates are not "to the manor born," but are self-invited intruders, —we must needs abandon the notion of any primordial and absolute adaptation of plants and animals to their habitats, which may stand in lieu of explanation and so preclude our inquiring any further. The harmony of Nature and its admirable perfection need not be regarded as inflexible and changeless. Nor need Nature be likened to a statue or a cast in rigid bronze, but rather to an organism with play and

adaptability of parts, and life and even soul informing the whole. Under the former view Nature would be "the faultless monster which the world ne'er saw," but inscrutable as the Sphinx, whom it were vain, or worse, to question of the whence and whither. Under the other, the perfection of nature, if relative, is multifarious and ever renewed, and much that is enigmatical now may find explanation in some record of the past.

That the two species of redwood we are contemplating originated as they are and where they are, and for the part they are now playing, is, to say the least, not a scientific supposition, nor in any sense a probable one. Nor is it more likely that they are destined to play a conspicuous part in the future, or that they would have done so, even if the Indian's fires and white man's axe had spared them. The redwood of the coast (*Sequoia sempervirens*) had the stronger hold upon existence, forming as it did large forests throughout a narrow belt about 300 miles in length, and being so tenacious of life that every large stump sprouts into a copse. But it does not pass the Bay of Monterey, nor cross the line of Oregon, although so grandly developed not far below it. The more remarkable *Sequoia gigantea* of the Sierra exists in numbers so limited that the separate groves may be reckoned upon the fingers, and the trees of most of them have been counted, except near their southern limit, where they are said to be more copious. A species limited in individuals holds its existence by a precarious tenure; and this has a foothold only in a few sheltered spots, of a happy mean in temperature and locally favoured with moisture in summer. Even there, for some reason or other, the pines with which they are associated (*Pinus Lambertiana* and *P. ponderosa*), the firs (*Abies grandis* and *A. amabilis*), and even the incense-cedar (*Libocedrus decurrens*) possess a great advantage, and, though they strive in vain to emulate their size, wholly overpower the Sequoias in numbers. "To him that hath shall be given;" the force of numbers eventually wins. At least, in the commonly visited groves *Sequoia gigantea* is invested in its last stronghold, can neither advance into more exposed positions above, nor fall back into drier and barer ground below, nor hold its own in the long run where it is, under present conditions; and a little further drying of the climate, which must once have been much moister than now, would precipitate its doom. Whatever the individual longevity, certain if not speedy is the decline of a race in which a high death-rate afflicts the young. Seedlings of the big trees occur not rarely, indeed, but in meagre proportion to those of associated trees; and small indeed is the chance that any of these

will attain to "the days of the years of their fathers." "Few and evil" are the days of all the forest likely to be, while man, both barbarian and civilized, torments them with fires, fatal at once to seedlings and at length to the aged also. The forests of California, proud as the State may be of them, are already too scanty and insufficient for her uses; two lines, such as may be drawn with one sweep of a small brush over the map, would cover them all. The coast redwood, the most important tree in California, although a million times more numerous than its relative of the Sierra, is too good to live long. Such is its value for lumber and its accessibility that, judging the future by the past, it is not likely in its primæval growth to outlast its rarer fellow species.

Happily man preserves and desseminates as well as destroys. The species will probably be indefinitely preserved to science, and for ornamental and other uses, in its own and other lands; and the more remarkable individuals of the present day are likely to be sedulously cared for, all the more so as they become scarce.

Our third question remains to be answered: Have these famous Sequoias played in former times and upon a larger stage a more imposing part, of which the present is but the epilogue? We cannot gaze high up the huge and venerable trunks, which one crosses the continent to behold, without wishing that these patriarchs of the grove were able, like the long-lived antediluvians of scripture, to hand down to us through a few generations the traditions of centuries, and so tell us somewhat of the history of their race. Fifteen hundred annual layers have been counted, or satisfactorily made out, upon one or two fallen trunks; it is probable that close to the heart of some of the living trees may be found the circle that records the year of our Saviour's nativity. A few generations of such trees might carry the history a long way back; but the ground they stand upon, and the marks of very recent geological change and vicissitude in the region around, testify that not very many such generations can have flourished just there, at least in an unbroken series. When their site was covered by glaciers these Sequoias must have occupied other stations, if, as there is reason to believe, they then existed in the land.

I have said that the redwoods have no near relatives in the country of their abode, and none of their genus anywhere else. Perhaps something may be learned of their genealogy by inquiring of such relatives as they have. There are only two of any particular nearness of kin; and they are far away. One is the bald cypress, our southern cypress (*Taxodium*), inhabiting

the swamps of the Atlantic coast from Maryland to Texas, thence extending into Mexico: it is well known as one of the largest trees of our Atlantic forest-district; and although it never (except perhaps in Mexico, and in rare instances) attains the portliness of its western relatives, yet it may equal them in longevity. The other relative is *Glyptostrobus*, a sort of modified *Taxodium*, being about as much like our bald cypress as one species of redwood is like the other.

Now species of the same type, especially when few and the type peculiar, are in a general way associated geographically, *i. e.* inhabit the same country or (in a large sense) the same region. Where it is not so, where near relatives are separated, there is usually something to be explained. Here is an instance. These four trees, sole representatives of their tribe, dwell almost in three separate quarters of the world—the two redwoods in California, the bald cypress in Atlantic North America, its near relative, *Glyptostrobus*, in China.

It was not always so. In the tertiary period, the geological botanists assure us, our own very *Taxodium*, or bald cypress, and a *Glyptostrobus* exceedingly like the present Chinese tree, and more than one *Sequoia* coexisted in a fourth quarter of the globe, viz. in Europe! This brings up the question: Is it possible to bridge over these four wide intervals of space and the much vaster interval of time, so as to bring these extraordinarily separated relatives into connexion? The evidence which may be brought to bear upon this question is various and widely scattered. I bespeak your patience while I endeavour to bring together in an abstract the most important points of it.

Some interesting facts may come out by comparing generally the botany of the three remote regions, each of which is the sole home of one of these three genera—i. e. *Sequoia* in California, *Taxodium* in the Atlantic United States, and *Glyptostrobus* in China, which compose the whole of the peculiar tribe under consideration.

Note then, first, that there is another set of three or four peculiar trees, in this case of the yew family, which has just the same peculiar distribution, and which therefore may have the same explanation, whatever that explanation be. The genus *Torreya*, which commemorates our botanical Nestor and a former president of this association (Dr. Torrey), was founded upon a tree rather lately discovered (that is, about thirty-five years ago) in northern Florida. It is a noble yew-like tree and very local, being known only for a few miles along the shores of a single river. It seems as if it had somehow been crowded down out of the Alleghanies into its present limited

southern quarters; for in cultivation it evinces a northern hardiness. Now another species of *Torreya* is a characteristic tree of Japan; and the same, or one very like it indeed, inhabits the Himalayas—belongs therefore to the Eastern Asiatic temperate region, of which China is a part, and Japan, as we shall see, the portion most interesting to us. There is only one more species of *Torreya*; and that is a companion of the redwoods in California; it is the tree locally known under the name of the California nutmeg. In this case the three are near brethren, species of the same genus, known nowhere else than in these three habitats.

Moreover the *Torreya* of Florida has growing with it a yew tree, and the trees of that grove are the only yew trees of Eastern America; for the yew of our northern woods is a decumbent shrub. The only other yew trees in America grow with the redwoods and the other *Torreya* in California, and more plentifully further north, in Oregon. A yew tree equally accompanies the *Torreya* of Japan and the Himalayas; and this is apparently the same as the common yew of Europe.

So we have three groups of trees of the great coniferous order which agree in this peculiar geographical distribution:—the redwoods and their relatives, which differ widely enough to be termed a different genus in each region; the Torreyas, more nearly akin, merely a different species in each region; the yews, perhaps all of the same species, perhaps not quite that (for opinions differ and can hardly be brought to any decisive test). The yews of the Old World, from Japan to Western Europe, are considered the same; the very local one in Florida is slightly different; that of California and Oregon differs a very little more; but all of them are within the limits of variation of many a species. However that may be, it appears to me that these several instances all raise the same question, only with a different degree of emphasis, and, if to be explained at all, will have the same kind of explanation. But the value of the explanation will be in proportion to the number of facts it will explain.

Continuing the comparison between the three regions with which we are concerned, we note that each has its own species of pines, firs, larches, &c., and of a few deciduous-leaved trees, such as oaks and maples; all of which have no peculiar significance for the present purpose, because they are of genera which are common all round the northern hemisphere. Leaving these out of view, the noticeable point is that the vegetation of California is most strikingly unlike that of the Atlantic United States. They possess some plants, and some peculiarly American plants, in common—enough to show, as I imagine, that

the difficulty was not in the getting from the one district to the other, or into both from a common source, but in abiding there. The primordially unbroken forest of Atlantic North America, nourished by rainfall distributed throughout the year, is widely separated from the western region of sparse and discontinuous tree-belts of the same latitude on the western side of the continent, where summer rain is wanting or nearly so, by immense treeless plains and plateaux of more or less aridity, traversed by longitudinal mountain-ranges of a similar character. Their nearest approach is at the north, in the latitude of Lake Superior, where, on a more rainy line, trees of the Atlantic forest and that of Oregon may be said to interchange. The change of species and of the aspect of vegetation in crossing, say on the forty-seventh parallel, is slight in comparison with that on the thirty-seventh or near it. Confining our attention to the lower latitude, and under the exceptions already specially noted, we may say that almost every characteristic form in the vegetation of the Atlantic States is wanting in California, and the characteristic plants and trees of California are wanting here.

California has no *Magnolia*, nor tulip-trees, nor star-anise tree, no so-called papaw (*Asimina*), no barberry of the common single-leaved sort, no *Podophyllum* or other of the peculiar associated genera, no *Nelumbo* nor white water-lily, no prickly ash nor sumach, no loblolly-bay nor *Stuartia*, no basswood or linden-trees, neither locust, honey-locust, coffee-trees (*Gymnocladus*), nor yellow-wood (*Cladrastis*), nothing answering to *Hydrangea* or witch-hazel, to gum-trees (*Nyssa* and *Liquidambar*), *Viburnum* or *Diervilla*; it has few asters and golden-rods, no lobelias, no huckle-berries, and hardly any blue-berries—no *Epigæa*, charm of our earliest eastern spring, tempering an icy April wind with a delicious wild fragrance—no *Kalmia*, nor *Clethra*, nor holly, nor persimmon—no catalpa tree, nor trumpet-creeper (*Tecoma*)—nothing answering to sassafras, or to benzoin tree, or to hickory—neither mulberry nor elm—no beech, true chestnut, hornbeam, nor ironwood, nor a proper birch tree; and the enumeration might be continued very much further by naming herbaceous plants and others familiar only to botanists.

In their place California is filled with plants of other types, trees, shrubs, and herbs, of which I will only remark that they are, with one or two exceptions, as different from the plants of the eastern Asiatic region with which we are concerned (Japan, China, and Mandchuria) as they are from those of Atlantic North America. Their near relatives, when they have any in other lands, are mostly southward, on the Mexican plateau, or

many as far south as Chili. The same may be said of the plants of the intervening great plains, except that northward and in the subsaline vegetation there are some close alliances with the flora of the steppes of Siberia. And along the crests of high mountain-ranges the arctic alpine flora has sent southward more or less numerous representatives through the whole length of the country.

If we now compare, as to their flora generally, the Atlantic United States with Japan, Mandchuria, and Northern China, *i. e.* eastern North America with eastern North Asia (half the earth's circumference apart), we find an astonishing similarity. The larger part of the genera of our own region which I have enumerated as wanting in California are present in Japan or Mandchuria, along with many other peculiar plants, divided between the two. There are plants enough of the one region which have no representatives in the other. There are types which appear to have reached the Atlantic States from the south; and there is a larger infusion of subtropical Asiatic types into temperate China and Japan: among these there is no relationship between the two countries to speak of. There are also, as I have already said, no small number of genera and some species which, being common all round or partially round the northern temperate zone, have no special significance because of their occurrence in these two antipodal floras, although they have testimony to bear upon the general question of geographical distribution. The point to be remarked is that many or even most of the genera and species which are peculiar to North America as compared with Europe, and largely peculiar to Atlantic North America as compared with the Californian region, are also represented in Japan and Mandchuria, either by identical or by closely similar forms! The same rule holds on a more northward line, although not so strikingly. If we compare the plants, say of New England and Pennsylvania (lat. 45°–47°), with those of Oregon, and then with those of North-eastern Asia, we shall find many of our own curiously repeated in the latter, while only a small number of them can be traced along the route even so far as the western slope of the Rocky Mountains. And these repetitions of Eastern American types in Japan and neighbouring districts are in all degrees of likeness. Sometimes the one is undistinguishable from the other; sometimes there is a difference of aspect, but hardly of a tangible character; sometimes the two would be termed marked varieties if they grew naturally in the same forest or in the same region; sometimes they are what the botanist calls representative species, the one answering closely to the other, but with some differences regarded as specific; sometimes the

two are merely of the same genus, or not quite that, but of a single or very few species in each country,—when the point which interests us is that this peculiar limited type should occur in two antipodal places, and nowhere else.

It would be tedious and, except to botanists, abstruse to enumerate instances; yet the whole strength of the case depends upon the number of such instances. I propose, therefore, if the Association does me the honour to print this discourse, to append in a note a list of the more remarkable ones. But I would here mention two or three cases as specimens.

Our *Rhus toxicodendron*, or poison-ivy, is very exactly repeated in Japan, but is found in no other part of the world, although a species much like it abounds in California. Our other poisonous *Rhus* (*R. venenata*), commonly called poison dogwood, is in no way represented in Western America, but has so close an analogue in Japan that the two were taken for the same by Thunberg and Linnæus, who called them *R. vernix*.

Our northern fox-grape (*Vitis labrusca*) is wholly confined to the Atlantic States, except that it reappears in Japan and that region.

The original *Wistaria* is a woody leguminous climber with showy blossoms, native to the Middle Atlantic States; the other species, which we so much prize in cultivation, *W. sinensis*, is from China, as its name denotes, or perhaps only from Japan, where it is certainly indigenous.

Our yellow wood (*Cladrastis*) inhabits a very limited district on the western slope of the Alleghanies. Its only and very near relative (*Maackia*) is in Mandchuria.

The *Hydrangeas* have some species in our Alleghany region. All the rest belong to the Chino-Japanese region and its continuation westward. The same may be said of *Philadelphus*, except that there are one or two mostly very similar in California and Oregon.

Our blue cohosh (*Caulophyllum*) is confined to the woods of the Atlantic States, but has lately been discovered in Japan. A peculiar relative of it, *Diphylleia*, confined to the higher Alleghanies, is also repeated in Japan, with a slight difference, so that it may barely be distinguished as another species. Another relative is our twin leaf, *Jeffersonia*, of the Alleghany region alone. A second species has lately turned up in Mandchuria. A relative of this is *Podophyllum*, our mandrake, a common inhabitant of the Atlantic United States, but found nowhere else. There is one other species of it; and that is in the Himalayas. Here are four most peculiar genera of one family, each of a single species in the Atlantic United States,

which are duplicated on the other side of the world, either in identical or almost identical species, or in an analogous species, while nothing else of the kind is known in any other part of the world.

I ought not to omit ginseng, the root so prized by the Chinese, which they obtained from their northern provinces and Mandchuria, and which is now known to inhabit Corea and Northern Japan. The Jesuit Fathers identified the plant in Canada and the Atlantic States, brought over the Chinese name by which we know it, and established the trade in it, which was for many years most profitable. The exportation of ginseng to China has probably not yet entirely ceased. Whether the Asiatic and the Atlantic American ginsengs are exactly of the same species or not is somewhat uncertain; but they are hardly if at all distinguishable.

There is a shrub, *Elliottia*, which is so rare and local that it is known only at two stations on the Savannah river in Georgia. It is of peculiar structure, and was without near relative until one was lately discovered in Japan (in *Tripetaleia*) so like it as hardly to be distinguishable except by having the parts of the blossom in threes instead of fours, a difference which is not uncommon in the same genus or even in the same species.

Suppose *Elliottia* had happened to be collected only once, a good while ago, and all knowledge of the limited and obscure locality was lost; and meanwhile the Japanese form came to be known. Such a case would be parallel with an actual one. A specimen of a peculiar plant, *Shortia galacifolia*, was detected in the herbarium of the elder Michaux, who collected it (as his autograph ticket shows) somewhere in the high Alleghany mountains more than eighty years ago. No one has seen the living plant since, or knows where to find it, if haply it still flourishes in some secluded spot. At length it is found in Japan; and I had the satisfaction of making the identification*. One other relative is also known in Japan; and another, still unpublished, has just been detected in Thibet.

Whether the Japanese and the Alleghanian plants are exactly the same or not, it needs complete specimens of the two to settle. So far as we know they are just alike. And even if some difference were discerned between them, it would not appreciably alter the question as to how such a result came to pass. Each and every one of the analogous cases I have been detailing (and very many more could be mentioned) raises the same question and would be satisfied with the same answer.

* Amer. Journ. Science, 1867, p. 402; Proc. Amer. Acad. viii. p. 244.

These singular relations attracted my curiosity early in the course of my botanical studies, when comparatively few of them were known, and my serious attention in later years, when I had numerous and new Japanese plants to study in the collections made by Messrs. Williams and Morrow during Commodore Perry's visit in 1853, and especially by Mr. Charles Wright in Commodore Rodgers's expedition in 1855. I then discussed this subject somewhat fully, and tabulated the facts within my reach*.

This was before Heer had developed the rich fossil botany of the arctic zone, before the immense antiquity of existing species of plants was recognized, and before the publication of Darwin's now famous volume on the Origin of Species had introduced and familiarized the scientific world with those now current ideas respecting the history and vicissitudes of species, with which I attempted to deal in a tentative and feeble way.

My speculation was based upon the former glaciation of the northern temperate zone, and the inference of a warmer period preceding (and perhaps following). I considered that our own present vegetation, or its proximate ancestry, must have occupied the arctic and subarctic regions in pliocene times, and that it had been gradually pushed southward as the temperature lowered and the glaciation advanced even beyond its present habitation—that plants of the same stock and kindred, probably ranging round the arctic zone as the present arctic species do, made their forced migration southward upon widely different longitudes, and receded more or less as the climate grew warmer—that the general difference of climate which marks the eastern and the western sides of the continents (the one extreme, the other mean) was doubtless even then established, so that the same species and the same sorts of species would be likely to secure and retain foothold in the similar climates of Japan and the Atlantic United States, but not in intermediate regions of different distribution of heat and moisture, so that different species of the same genus, as in *Torreya*, or different genera of the same group, as Redwood, *Taxodium*, and *Glyptostrobus*, or different associations of forest trees, might establish themselves each in the region best suited to its particular requirements, while they would fail to do so in any other. These views implied that the sources of our actual vegetation, and the explanation of these peculiarities, were to be sought in and presupposed an ancestry in pliocene or still earlier times occupying the high northern regions. And it was thought that the occurrence of peculiarly North-

* Mem. Amer. Acad. vol. vi.

American genera in Europe in the tertiary period (such as *Taxodium*, *Carya*, *Liquidambar*, *Sassafras*, *Negundo*, &c.) might be best explained on the assumption of early interchange and diffusion through North Asia, rather than by that of the fabled Atlantis.

The hypothesis supposed a gradual modification of species in different directions under altering conditions, at least to the extent of producing varieties, subspecies, and representative species, as they may be variously regarded—likewise the single and local origination of each type, which is now almost universally taken for granted.

The remarkable facts in regard to the Eastern-American and Asiatic floras, which these speculations were to explain, have since increased in number—more especially through the admirable collections of Dr. Maximowicz in Japan and adjacent countries, and the critical comparisons he has made and is still engaged upon.

I am bound to state that in a recent general work* by a distinguished botanist, Professor Grisebach, of Göttingen, these facts have been emptied of all special significance, and the relations between the Japanese and the Atlantic United States floras declared to be no more intimate than might be expected from the situation, climate, and present opportunity of interchange. This extraordinary conclusion is reached by regarding as distinct species all the plants common to both countries between which any differences have been discerned, although such differences would probably count for little if the two inhabited the same country, thus transferring many of my list of identical to that of representative species, and then by simply eliminating from consideration the whole array of representative species, *i. e.* all cases in which the Japanese and the American plant are not exactly alike,—as if, by pronouncing the cabalistic word *species*, the question were settled, or rather the greater part of it remanded out of the domain of science—as if, while complete identity of forms implies community of region, any thing short of it carries no presumption of the kind—so leaving all these singular duplicates to be wondered at, indeed, but wholly beyond the reach of inquiry.

Now the only known cause of such likeness is inheritance; and as all transmission of likeness is with some difference in individuals, and as changed conditions have resulted, as is well known, in very considerable differences, it seems to me that if the high antiquity of our actual vegetation could be rendered probable, not to say certain, and the former habitation of any of our species, or of very near relatives of them in high northern

* Die Vegetation der Erde nach ihrer klimatischen Anordnung. 1871.

regions could be ascertained, my whole case would be made out. The needful facts, of which I was ignorant when my essay was published, have now been for some years made known, thanks mainly to the researches of Heer upon ample collections of arctic fossil plants. These are confirmed and extended through new investigations by Heer and Lesquereux, the results of which have been indicated to me by the latter.

The *Taxodium* which everywhere abounds in the miocene formations in Europe, has been specifically identified, first by Goeppert, then by Heer, with our common cypress of the Southern States. It has been found fossil in Spitzbergen, Greenland, and Alaska, in the latter country along with the remains of another form, distinguishable, but very like the common species; and this has been identified by Lesquereux in the miocene of the Rocky Mountains. So there is one species of tree which has come down essentially unchanged from the tertiary period, which for a long while inhabited both Europe and North America, and also at some part of the period the region which geographically connects the two (once doubtless much more closely than now), but has survived only in the Atlantic United States and Mexico.

The same *Sequoia* which abounds in the same miocene formations in Northern Europe has been abundantly found in those of Iceland, Spitzbergen, Greenland, Mackenzie river, and Alaska. It is named *S. Langsdorffii*, but is pronounced to be very much like *S. sempervirens*, our living redwood of the Californian coast, and to be the ancient representative of it. Fossil specimens of a similar, if not the same, species have been recently detected in the Rocky Mountains by Hayden, and determined by our eminent palæontological botanist, Lesquereux; and he assures me that he has the common redwood itself from Oregon, in a deposit of tertiary age. Another *Sequoia* (*S. Sternbergii*), discovered in miocene deposits in Greenland, is pronounced to be the representative of *S. gigantea*, the big tree of the Californian sierra. If the *Taxodium* of tertiary time in Europe and throughout the arctic regions is the ancestor of our present bald cypress, which is assumed in regarding them as specifically identical, then I think we may, with our present light, fairly assume that the two redwoods of California are the direct or collateral descendents of the two ancient species which so closely resemble them.

The forests of the arctic zone in tertiary times contained at least three other species of *Sequoia*, as determined by their remains, one of which, from Spitzbergen, also much resembles the common redwood of California. Another, "which appears to

have been the commonest coniferous tree on Disco," was common in England and some other parts of Europe. So the Sequoias, now remarkable for their restricted station and numbers, as well as for their extraordinary size, are of an ancient stock; their ancestors and kindred formed a large part of the forests which flourished throughout the polar regions, now desolate and ice-clad, and which extended into low latitudes in Europe. On this continent one species at least had reached to the vicinity of its present habitat before the glaciation of the region. Among the fossil specimens already found in California, but which our trustworthy palæontological botanist has not yet had time to examine, we may expect to find evidence of the early arrival of these two redwoods upon the ground which they now, after much vicissitude, scantily occupy.

Differences of climate, or circumstances of migration, or both, must have determined the survival of *Sequoia* upon the Pacific, and of *Taxodium* upon the Atlantic coast; and still the redwoods will not stand in the east, nor could our *Taxodium* find a congenial station in California.

As to the remaining near relative of *Sequoia*, the Chinese *Glyptostrobus*, a species of it, and its veritable representative, was contemporaneous with *Sequoia* and *Taxodium*, not only in temperate Europe, but throughout the arctic regions from Greenland to Alaska. Very similar would seem to have been the fate of a more familiar gymnospermous tree, the gingko or *Salisburia*. It is now indigenous to Japan only. Its ancestor, as we may fairly call it (since, according to Heer, "it corresponds so entirely with the living species that it can scarcely be separated from it"), once inhabited Northern Europe and the whole arctic region round to Alaska, and had even a representative further south in our Rocky-Mountain district. For some reason, this and *Glyptostrobus* survived only on the shores of Eastern Asia.

Libocedrus, on the other hand, appears to have cast in its lot with the Sequoias. Two species, according to Heer, were with them in Spitzbergen. Of the two now living, *L. decurrens* (the incense cedar) is one of the noblest associates of the present redwoods; the other is far south, in the Andes of Chili.

The genealogy of the Torreyas is more obscure; yet it is not unlikely that the yew-like trees named *Taxites*, which flourished with the Sequoias in the tertiary arctic forests, are the remote ancestors of the three species of *Torreya*, now severally in Florida, in California, and in Japan.

As to the pines and firs, these were more numerously asso-

ciated with the ancient Sequoias of the polar forests than with their present representatives, but in different species, apparently more like those of Eastern than of Western North America. They must have encircled the polar zone then, as they encircle the present temperate zone now.

I must refrain from all enumeration of the angiospermous or ordinary deciduous trees and shrubs which are now known by their fossil remains to have flourished throughout the polar regions when Greenland better deserved its name, and enjoyed the present climate of New England and New Jersey. Then Greenland and the rest of the north abounded with oaks, representing the several groups of species which now inhabit both our eastern and western forest districts—several poplars, one very like our balsam poplar or balm-of-Gilead tree—more beeches than there are now, a hornbeam, and a hop hornbeam, some birches, a persimmon, and a plane-tree, near representatives of those of the Old World, at least of Asia, as well as of Atlantic North America, but all wanting in California—one *Juglans* like the walnut of the Old World, and another like our black walnut—two or three grape-vines, one near our Southern fox grape or muscadine, the other near our Northern frost grape—a *Tilia* very like our basswood of the Atlantic States only, a *Liquidambar*, a *Magnolia* which recalls our *M. grandiflora*, a *Liriodendron*, sole representative of our tulip-tree, and a sassafras very like the living tree.

Most of these, it will be noticed, have their nearest or their only living representatives in the Atlantic States—and when elsewhere, mainly in Eastern Asia. Several of them, or of species like them, have been detected in our tertiary deposits west of the Mississippi, by Newberry and Lesquereux.

Herbaceous plants, as it happens, are rarely preserved in a fossil state; else they would probably supply additional testimony to the antiquity of our existing vegetation, its wide diffusion over the northern and now frigid zone, and its enforced migrations under changes of climate.

Concluding, then, as we must, that our existing vegetation, as a whole, is a continuation of that of the tertiary period, may we suppose that it absolutely originated then? Evidently not. The preceding Cretaceous period has furnished to Carruthers in Europe a fossil fruit like that of the *Sequoia gigantea* of the famous groves, associated with pines of the same character as those that accompany the present tree—has furnished to Heer, from Greenland, two more Sequoias, one of them identical with a tertiary species, and one nearly allied to *Sequoia Langsdorfii*, which in turn is a probable ancestor of the common Californian redwood—has furnished to Lesquereux in North America the

remains of another ancient *Sequoia*, a *Glyptostrobus*, a *Liquidambar* which well represents our sweet-gum tree, oaks analogous to living ones, leaves of a plane-tree which are also in the tertiary and are scarcely distinguishable from our own *Platanus occidentalis*, of a magnolia and tulip-tree, and "of a sassafras undistinguishable from our living species." I need not continue the enumeration. Suffice it to say that the facts will justify the conclusion which Lesquereux (a very scrupulous investigator) has already announced, "That the essential types of our actual flora are marked in the Cretaceous period, and have come to us after passing, without notable changes, through the tertiary formations of our continent."

According to these views, as regards plants at least, the adaptation to successive times and changed conditions has been maintained, not by absolute renewals, but by gradual modifications. I, for one, cannot doubt that the present existing species are the lineal successors of those that garnished the earth in the old time before them, and that they were as well adapted to their surroundings then as those which flourish and bloom around us are to their conditions now. Order and exquisite adaptation did not wait for man's coming, nor were they ever stereotyped. Organic Nature (by which I mean the system and totality of living things, and their adaptation to each other and to the world), with all its apparent and indeed real stability, should be likened, not to the ocean, which varies only by tidal oscillations from a fixed level to which it is always returning, but rather to a river so vast that we can neither discern its shores nor reach its sources, whose onward flow is not less actual because too slow to be observed by the Ephemeræ which hover over its surface or are borne upon its bosom.

Such ideas as these, though still repugnant to some, and not long since to many, have so possessed the minds of the naturalists of the present day that hardly a discourse can be pronounced or an investigation prosecuted without reference to them. I suppose that the views here taken are little if at all in advance of the average scientific mind of the day. I cannot regard them as less noble than those which they are succeeding.

An able philosophical writer, Miss Frances Power Cobbe, has recently and truthfully said* :—

"It is a singular fact that when we can find out how any thing is done, our first conclusion seems to be that God did not do it. No matter how wonderful, how beautiful, how intimately complex and delicate has been the machinery which

* "Darwinism in Morals," in Theological Review, April 1871.

has worked, perhaps for centuries, perhaps for millions of ages, to bring about some beneficent result, if we can but catch a glimpse of the wheels, its divine character disappears."

I agree with the writer that this first conclusion is premature and unworthy; I will add, deplorable. Through what faults or infirmities of dogmatism on the one hand and scepticism on the other it came to be so thought, we need not here consider. Let us hope, and I confidently expect, that it is not to last—that the religious faith which survived without a shock the notion of the fixity of the earth itself, may equally outlast the notion of the absolute fixity of the species which inhabit it—that, in the future even more than in the past, faith in an *order*, which is the basis of science, will not (as it cannot reasonably) be dissevered from faith in an *Ordainer*, which is the basis of religion.

VIII.—*Physico-chemical Investigations upon the Aquatic Articulata.* By M. Félix Plateau. Part II.*

The first part of my investigations, of which an abstract was published in this Journal in 1871 (vol. vii. p. 362), contained the results of my experiments on the causes of the death of the freshwater Articulata in sea-water, and of the marine Articulata in fresh water.

In the present memoir I take up three other interesting questions connected with the life of the aquatic Articulata—questions of detail indeed, the solution of which could not open any new vista in comparative physiology, but which, carefully treated, have led me by numerous experiments to curious and sometimes unexpected results.

I. *Experiments on the time during which the aquatic Articulata can remain in the water without coming to the surface to breathe.*

The swimming aquatic Articulata with aërial respiration (Coleoptera in the perfect state and Hemiptera) come frequently to the surface to renew their provision of air. If we prevent them from performing this operation, what will be the time during which they may with impunity be subjected to submersion? Is their resistance to asphyxia greater than that of terrestrial insects? or only equal or inferior to it?

The experiments were effected as follows: at the bottom of an open vase of the capacity of one litre, and full of ordinary spring water aërated, a smaller vessel containing about 200 cubic centimetres is placed; a piece of cotton net is stretched

* Bulletin de l'Acad. Roy. de Belgique, 2e sér. tome xxxiv. nos. 9 & 10, 1872. From an Abstract by the Author.